# DEVELOPMENT OF AN ECG IDENTIFICATION SYSTEM

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*Abstract* – The purpose of this paper is to present a new identification engine for an ECG identification system. The system identifies subjects based on a comparison of a patient's ECG with previously registered ECG feature parameters. These feature parameters are sampled from the intervals and durations of the electrocardiographic waves extracted using characteristic points appearing on the waveform of the second order derivative and are identified using discriminant analysis. Suitable combinations of feature parameters are selected and the accuracy of the proposed technique verified using ECGs from nine normal subjects.

*Keywords* – ECG, identification, discriminant analysis, feature parameter

## I. INTRODUCTION

The widespread use of telemedicine and home care techniques has increased the need for systems to protect patient data from leakage, theft or modification during transmission. Furthermore, a robust identification system is needed to ensure that the correct information is stored for each patient. ECG is a frequently used method for monitoring and checking a patient's condition. An identification system that utilizes some of the ECG feature parameters would improve the level of security and reliability of the information system without adding any data, a vital requirement for minimizing data volumes. For this purpose, we proposed a simpler and more practical system [1] than previous systems [2,3]. In this study, we improve on the identification engine using multiple discriminant analysis and demonstrate the performance of the discrimination process by experiments using ECGs from nine subjects.

## II. METHOD

In order to perform any identification process, feature parameters must be extracted from the ECG. In this study, we used the durations and intervals of the electrocardiographic waves. Four parameters (P wave duration, PQ interval, QRS interval and QT interval) are appropriate for this purpose, since they are not affected by the R-R interval or electrode conditions. The extraction of these parameters is performed by marking characteristic points on the ECG using the second order derivative waveform to emphasize their locations. An example of such marking is shown in fig. 1.

Discriminant analysis with two feature parameters is used to discriminate between the registered ECGs. A combination of two of the four feature parameters are used as the variate for analysis. Since testing showed that most covariance matrices calculated from the feature parameters of subjects are different, we applied Mahalanobis' generalized distance to the criterion for discrimination. The average, variance and covariance values are calculated from the first sequence of feature parameter data to fix the coefficients in the equation of the Mahalanobis' generalized distance for registration purposes. The discriminant analysis result is computed by selecting the smallest Mahalanobis' generalized distance. Using this approach, the system can discriminate between registered subjects within a single beat.

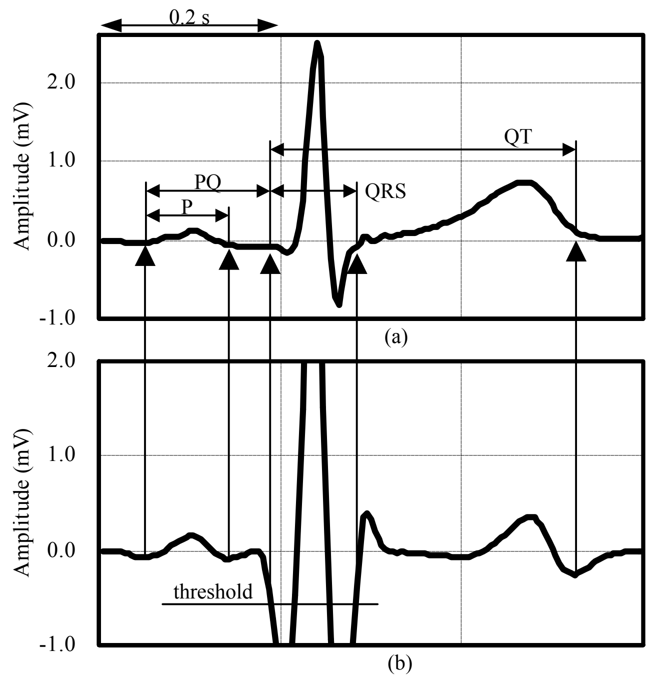


Fig. 1. Marking at characteristic points on ECG.
(a) : ECG
(b) : Second order derivative

## III. EXPERIMENT

The experimental system is divided into three parts. The first is an ECG measurement and AD conversion block, the second is a feature parameter extraction block and the third is a discriminant analysis block. The feature parameter extraction block extracts four feature parameters from sampled ECG data sequence on a beat-by-beat basis, and checks whether the values are within the allowable ranges of normal electrocardiographic waves. Two sequences are then selected from these feature parameter sequences and applied to the final block. Finally, a beat-by-beat discrimination result is obtained.

The experiment was performed using ECGs from nine normal subjects. Two sequences of ECG data were measured

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for each subject. The coefficients in the equation of a Mahalanobis' generalized distance were calculated from the first ECG data. Discriminant analysis was performed on the second ECG data. Table I shows the measurement conditions for the ECG measurement and AD conversion block. All possible feature parameter combinations were applied to the discriminant analysis to identify the optimum combination.

## IV. RESULTS

The details of the measured ECGs are shown in table II. The averages and the variances of the feature parameters from the measured ECGs are shown in table III.

Some examples of feature parameter distributions are shown in fig. 2 through fig. 4. Fig. 2 and fig. 3 show results from different sequences of ECG data from one subject. The distribution of the parameters from a second subject is shown in fig. 4.

The result of discriminant analysis is shown in table IV.

TABLE I
MEASUREMENT CONDITION

| | |
|---|---|
| Num. of samples | 100,000 |
| Filter | 0.06Hz HPF, 60Hz LPF, 50Hz BRF |
| AD converter | 500Hz, 12bit |
| Lead | Limb lead II |
| State of subject | Rest (sitting) |

TABLE II
OUTLINE OF THE DATA FROM NINE SUBJECTS

| Subject | Age | Date | ID | Num. of beats |
|---|---|---|---|---|
| A | 21 | Oct.19,2000 | A_1 | 218 |
| | | | A_2 | 224 |
| B | 23 | Oct.14,2000 | B_1 | 295 |
| | | | B_2 | 291 |
| C | 22 | Oct.11,2000 | C_1 | 202 |
| | | | C_2 | 201 |
| D | 35 | Feb.09,2001 | D_1 | 170 |
| | | | D_2 | 174 |
| E | 21 | Oct.19,2000 | E_1 | 260 |
| | | | E_2 | 275 |
| F | 22 | Feb.08,2001 | F_1 | 259 |
| | | | F_2 | 239 |
| G | 22 | Oct.11,2000 | G_1 | 275 |
| | | | G_2 | 255 |
| H | 24 | Oct.17,2000 | H_1 | 217 |
| | | | H_2 | 224 |
| I | 23 | Feb.08,2001 | I_1 | 227 |
| | | | I_2 | 226 |

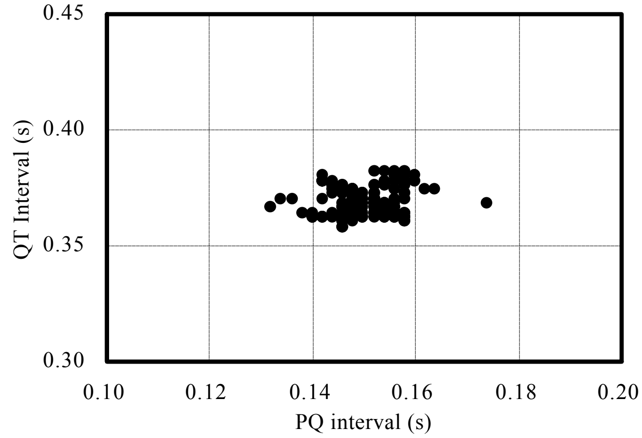

Fig. 2. Distribution of characteristic parameters. (data : A_1)

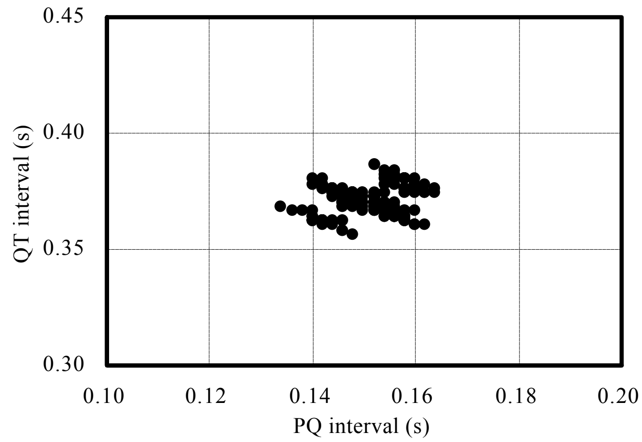

Fig. 3. Distribution of characteristic parameters. (data : A_2)

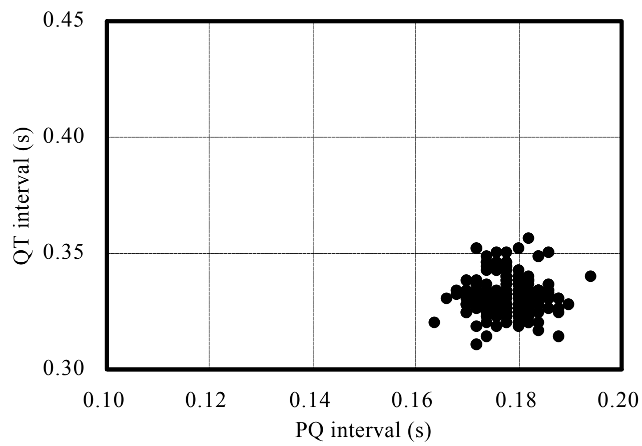

Fig. 4. Distribution of characteristic parameters. (data : G_1)

TABLE III
AVERAGES AND VARIANCES OF THE FEATURE PARAMETERS

| ID | | A_1 | B_1 | C_1 | D_1 | E_1 | F_1 | G_1 | H_1 | I_1 |
|---|---|---|---|---|---|---|---|---|---|---|
| Average | Tp | 0.105 | 0.094 | 0.116 | 0.088 | 0.104 | 0.101 | 0.099 | 0.105 | 0.097 |
| | Tqrs | 0.088 | 0.097 | 0.095 | 0.096 | 0.100 | 0.093 | 0.090 | 0.109 | 0.105 |
| | Tpq | 0.150 | 0.142 | 0.167 | 0.137 | 0.157 | 0.147 | 0.178 | 0.142 | 0.153 |
| | Tqt | 0.369 | 0.335 | 0.329 | 0.426 | 0.354 | 0.375 | 0.331 | 0.378 | 0.337 |
| Variance | Tp | 1.94E-5 | 6.55E-5 | 1.66E-4 | 2.48E-5 | 5.07E-5 | 7.58E-5 | 4.26E-5 | 7.15E-6 | 1.93E-4 |
| | Tqrs | 8.06E-7 | 1.10E-6 | 1.44E-6 | 1.01E-6 | 9.42E-7 | 1.24E-6 | 2.18E-6 | 9.89E-7 | 2.35E-6 |
| | Tpq | 1.78E-5 | 4.47E-5 | 4.18E-5 | 1.87E-5 | 3.32E-5 | 7.08E-5 | 1.45E-5 | 7.44E-6 | 8.45E-5 |
| | Tqt | 1.90E-5 | 2.45E-5 | 1.87E-5 | 6.27E-6 | 1.62E-5 | 2.42E-5 | 5.16E-5 | 1.27E-5 | 9.08E-5 |

The accuracy value quoted in the table is calculated from the number of beats correctly discriminated and the total number of beats.

## V. DISCUSSIONS

The statistical parameters listed in Table III were used as coefficients in the calculation of the Mahalanobis' generalized distance it is demonstrated that these parameters are suitable for discrimination purposes in fig. 2 through fig. 4. Fig. 2 and fig. 3, which show the distribution of feature parameters from the same subject, show a high degree of correlation. On the contrary, fig. 3 and fig.4, which show the distribution of feature parameters from different subjects, are significantly different.

Table IV shows the system performance for every possible pair of feature parameters. It can be seen that there is a large variation in achievable accuracy with the different combinations. In particular, use of the P wave duration results in a low discriminatory accuracy. This may be due to the small differences between subjects and from ambiguities in the placement of the characteristic points. The highest accuracy was achieved using the combination of QRS interval and QT interval parameters. All results with the exception of the C_2 data exceed ninety percent accuracy. Since the combination of QRS interval and PQ interval parameters also provided accurate results, it is expected that the use of a combination of these three feature parameters will improve the accuracy of the technique.

The ratio of the two amplitudes of the electrocardiographic waves is another possible parameter for use in this system, since it is not affected by variations in the amplitude of the ECG due to uncertain electrode conditions. The extension of the system to include this feature parameter may suppress any deterioration in performance that may occur when the number of subjects in the database is large.

TABLE IV
RESULTS OF DISCRIMINANT ANALYSIS

| Data ID | Accuracy [%] | | | | | |
|---|---|---|---|---|---|---|
| | P-QRS | P-PQ | P-QT | QRS-PQ | QRS-QT | PQ-QT |
| A_2 | 80.8 | 31.3 | 48.7 | 99.1 | 99.1 | 48.2 |
| B_2 | 73.2 | 38.5 | 4.1 | 89.0 | 90.4 | 46.4 |
| C_2 | 84.0 | 90.1 | 81.0 | 95.0 | 76.1 | 78.1 |
| D_2 | 60.3 | 56.3 | 99.4 | 44.8 | 99.4 | 99.4 |
| E_2 | 82.9 | 17.5 | 45.8 | 93.8 | 90.2 | 47.6 |
| F_2 | 63.6 | 7.5 | 86.6 | 67.4 | 99.2 | 87.0 |
| G_2 | 64.3 | 94.9 | 38.4 | 98.4 | 96.5 | 96.9 |
| H_2 | 80.4 | 84.4 | 29.5 | 79.0 | 97.3 | 24.1 |
| I_2 | 99.6 | 88.5 | 83.2 | 99.6 | 99.6 | 84.5 |

## VI. CONCLUSION

In this paper, we presented a new discrimination process for an ECG identification system and demonstrated the accuracy of the proposed technique using the ECGs from nine normal subjects. The results suggest that the system can discriminate between registered ECGs with an acceptable level of accuracy. It was also suggested that the addition of extra feature parameters to the discrimination system would further enhance the performance of the system.

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